Veto Photoelectronics for DarkSide-20k

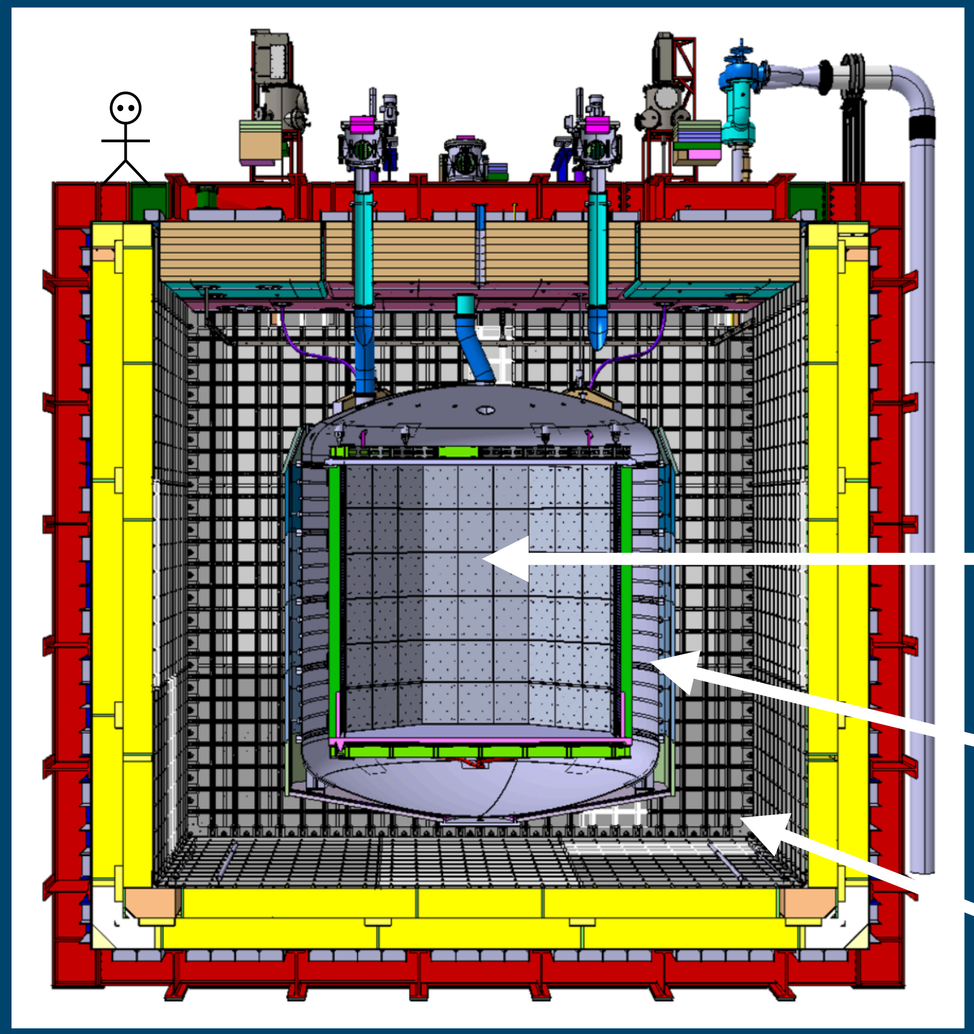
Transfer of Status

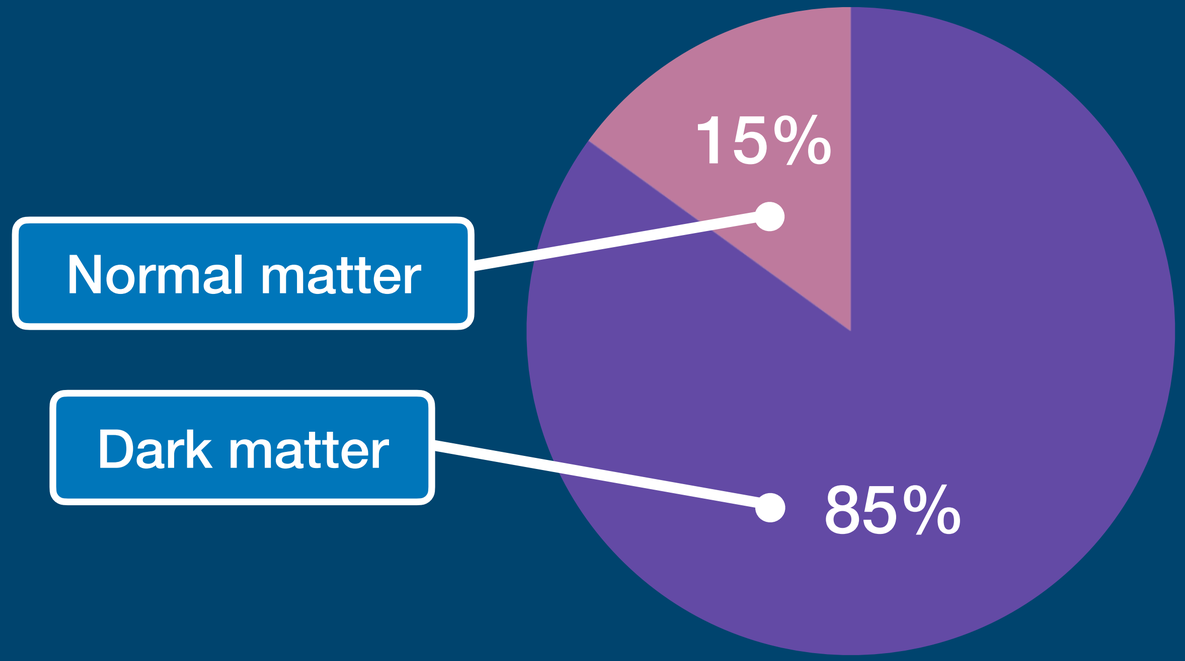
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DarkSide-20k





Normal matter

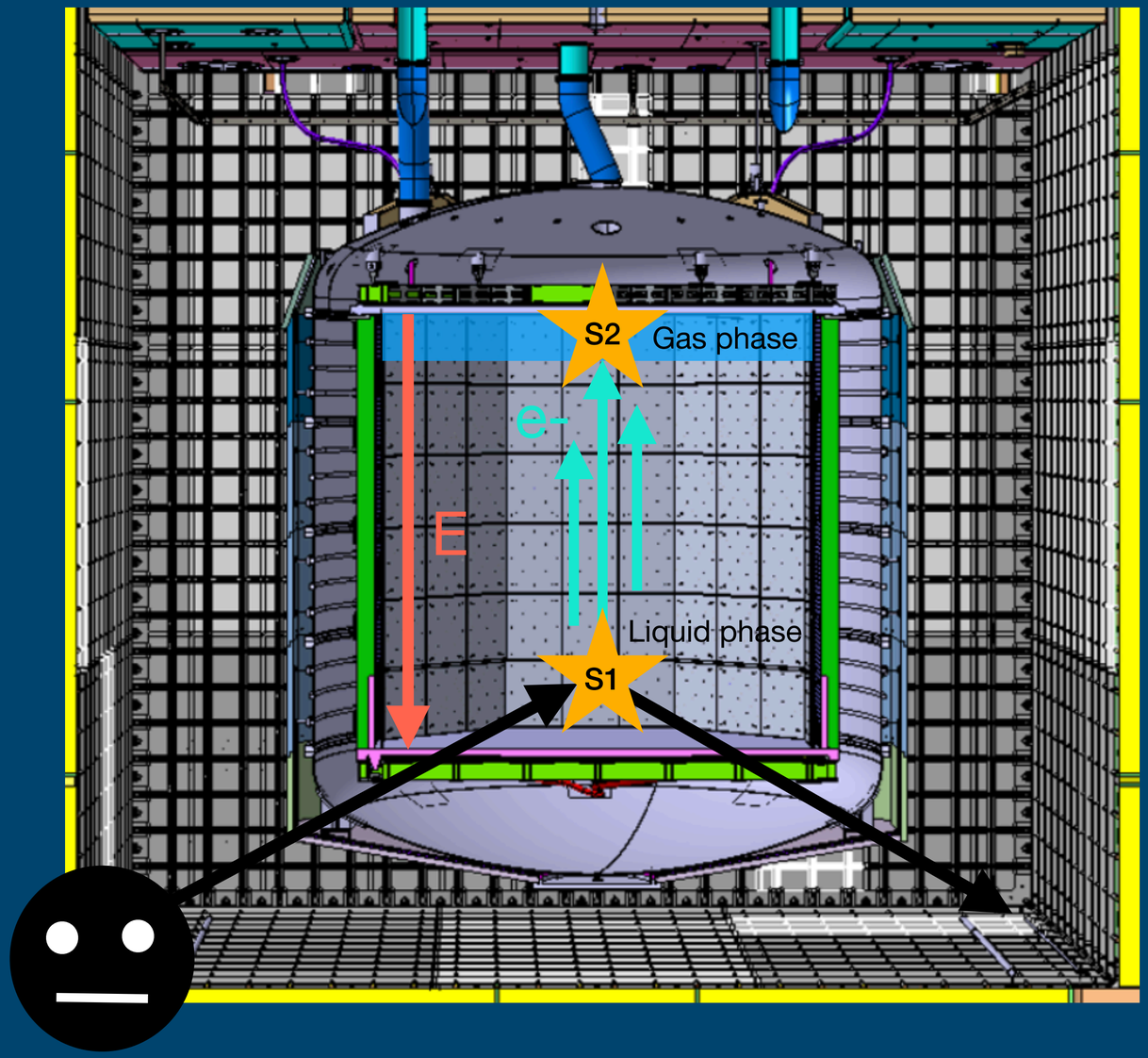
Dark matter

TPC - detect dark matter signal

Inner veto (IV) - tag radiogenic neutrons

Outer veto (OV) - tag cosmic muons

Signal Production



Dark matter scatters off argon

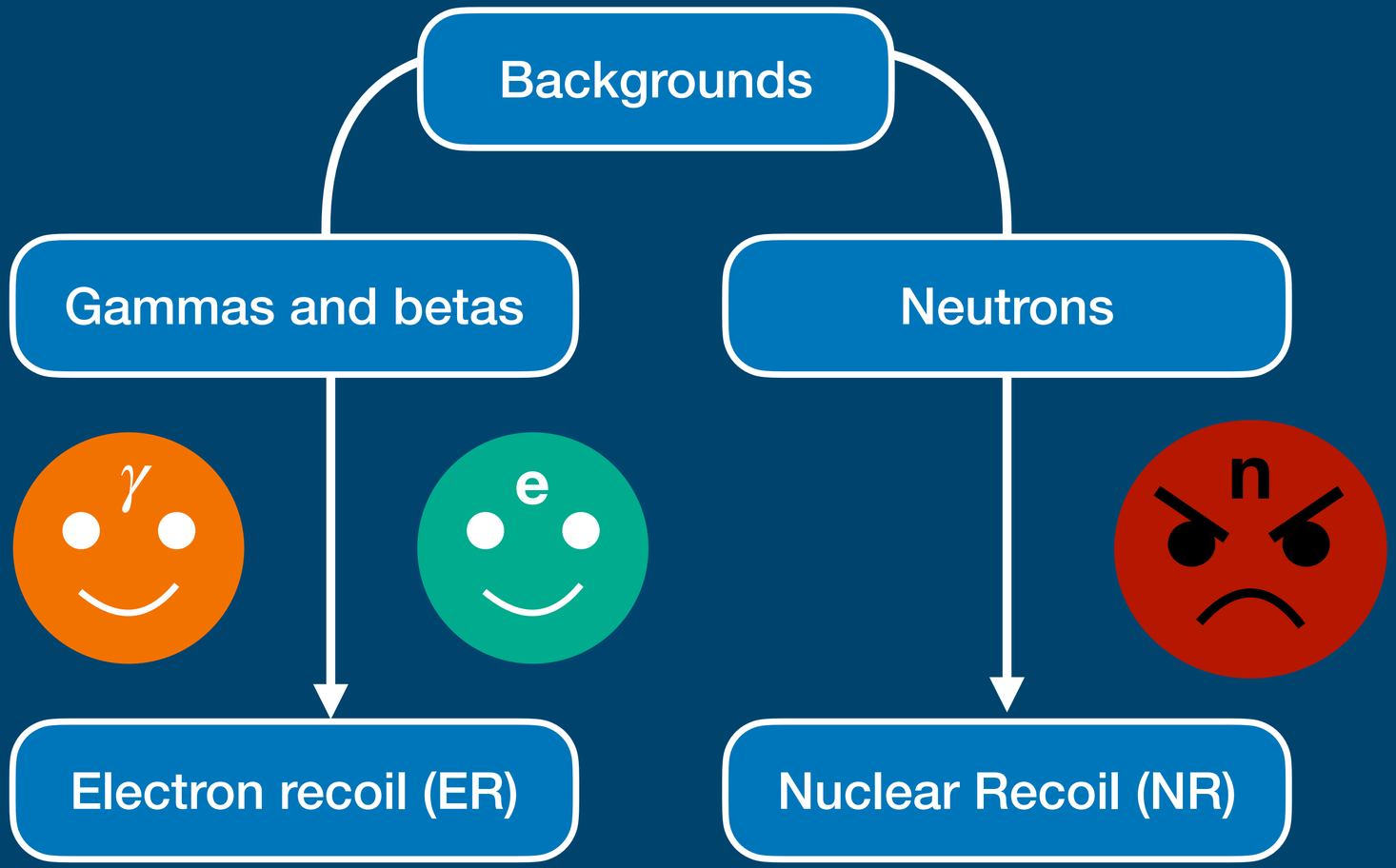
Atoms in TPC excited/ionised

Scintillation light - S1

Electrons drifted to high field gas phase

Electroluminescent light - S2

Pulse Shape Discrimination (PSD)

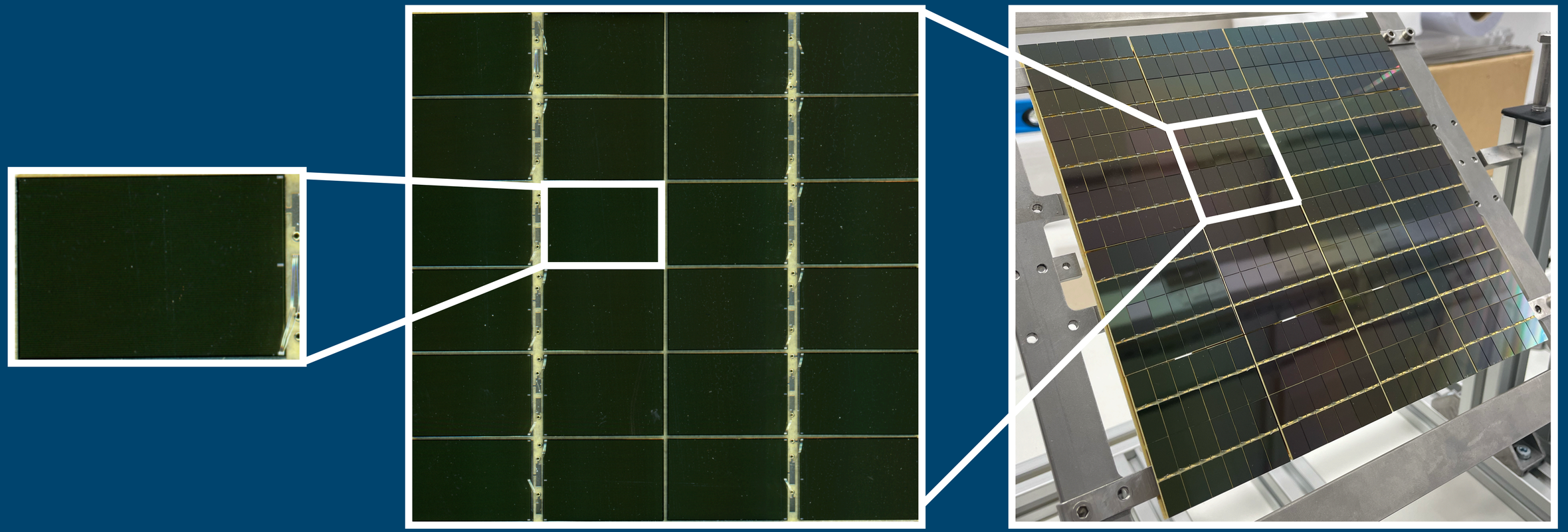


S1 significantly more prompt for NR than ER

Discriminate and remove ER backgrounds

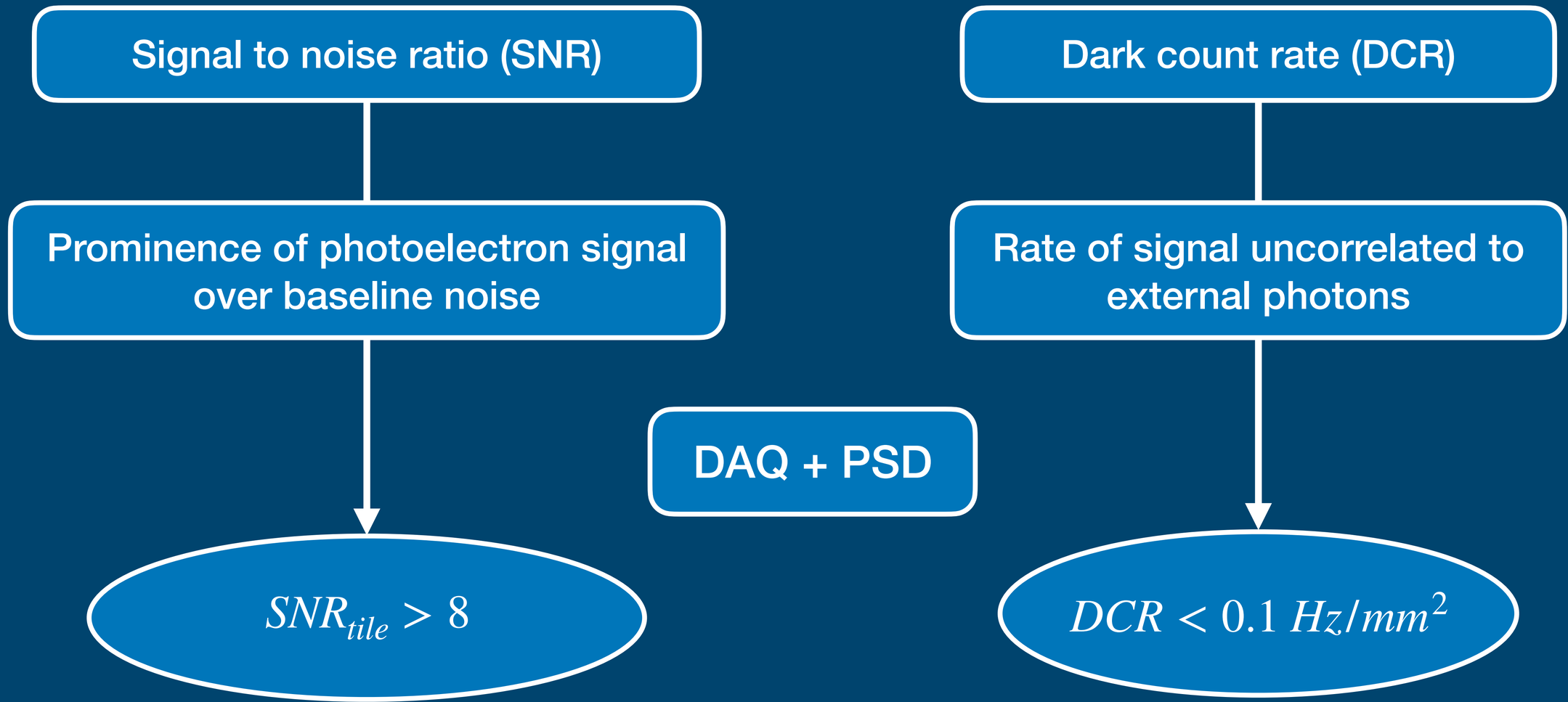
Leaves neutrons as the main background

Detecting S1/S2 Light

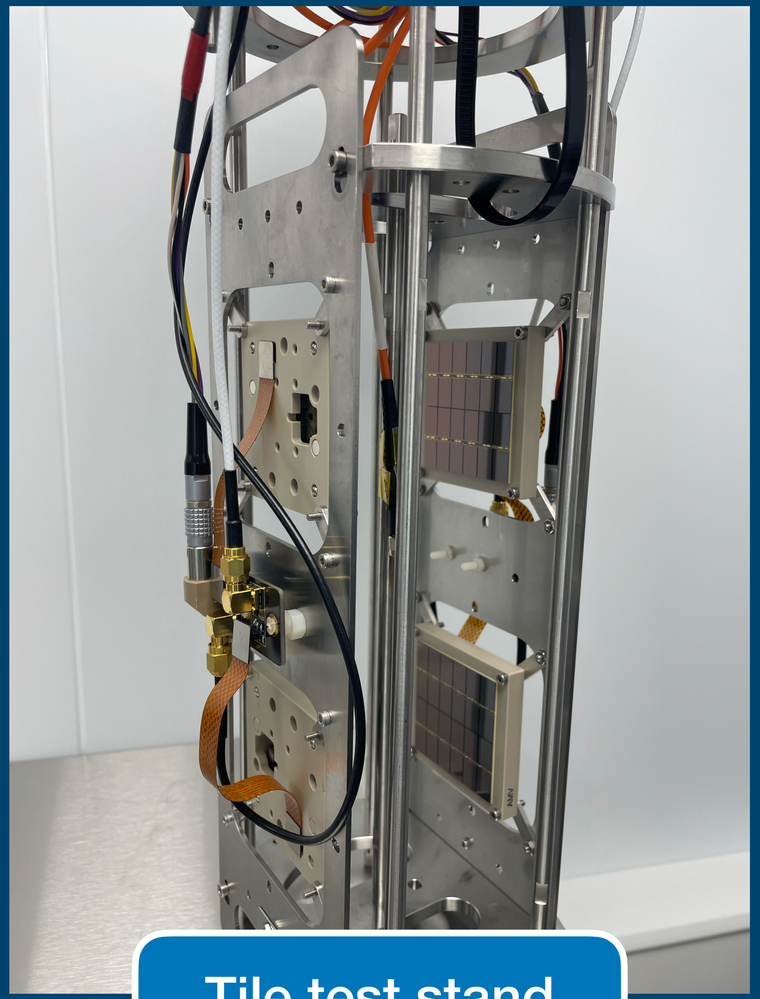




Tile and PDU Noise



Noise Characterisation



Tile test stand

Tested in liquid nitrogen

Pulse a laser at SiPM surface

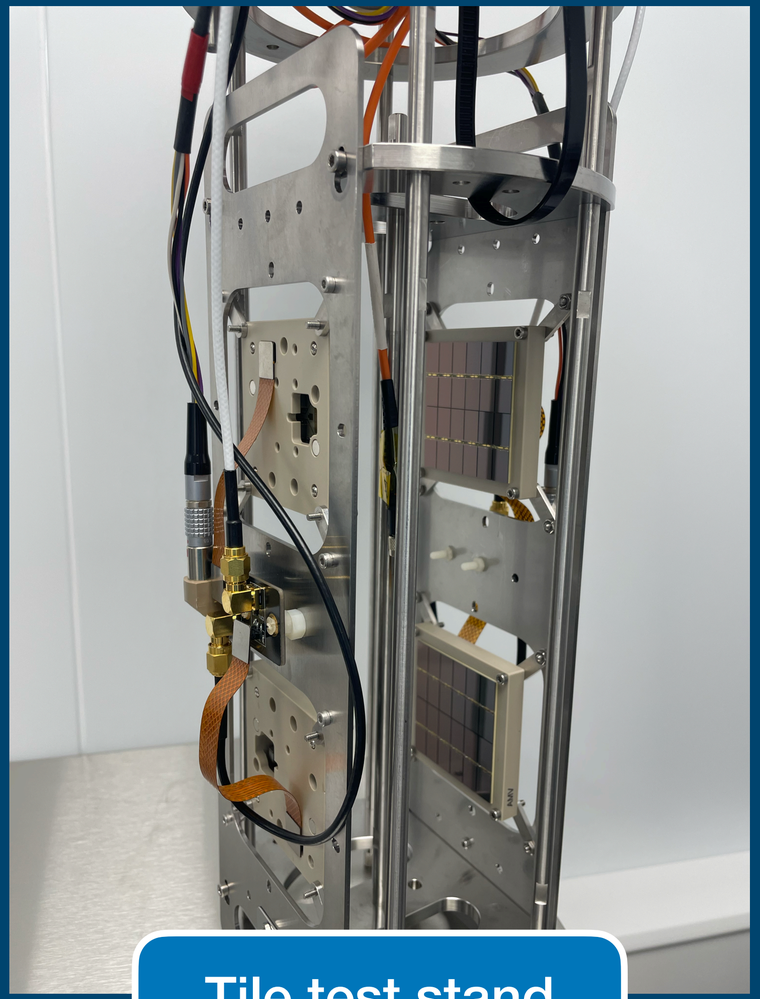
Record voltage response



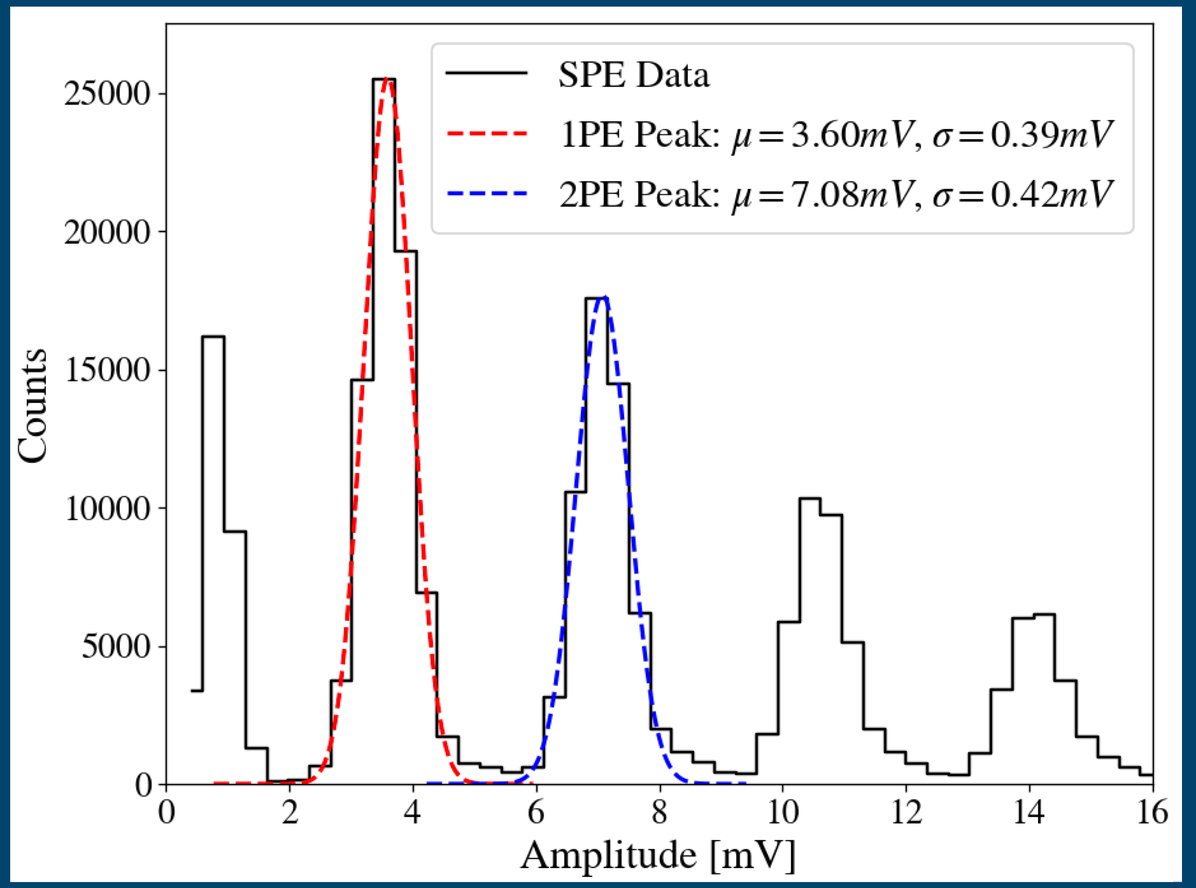
PDU testing

SNR

$$SNR = \frac{\mu_{2PE} - \mu_{1PE}}{RMS}$$



Tile test stand



Tile SPE Spectrum

Tile DCR

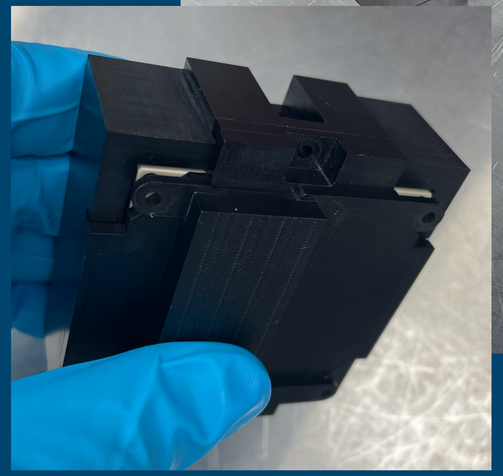
Eliminate external photons

Design and implement dark box

Hermetically enclose Tile

3 piece design + photon baffles





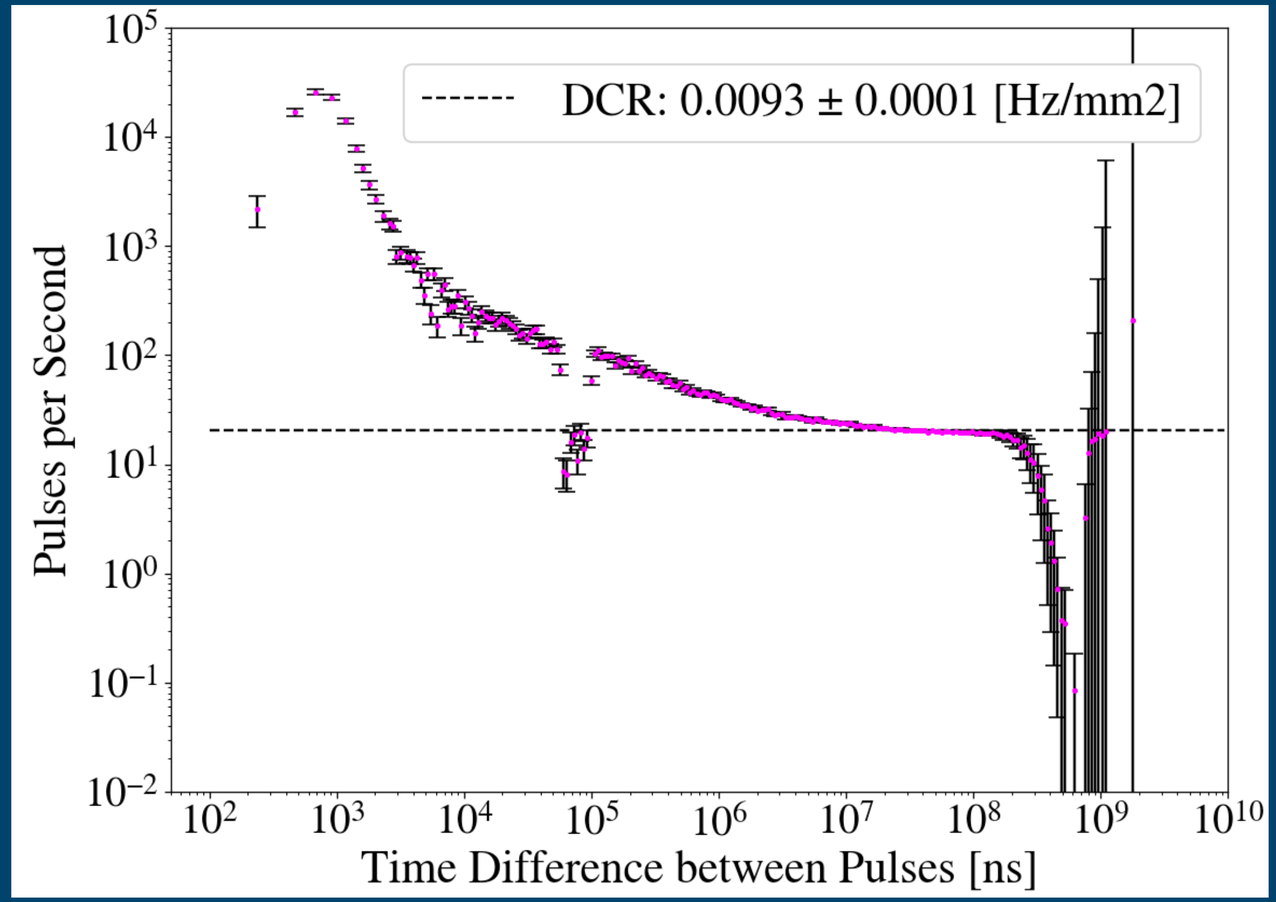
Tile DCR

Trigger on Tile voltage at 3.5mV

Measure time difference between pulses

At long times, distribution tends to uncorrelated noise rate

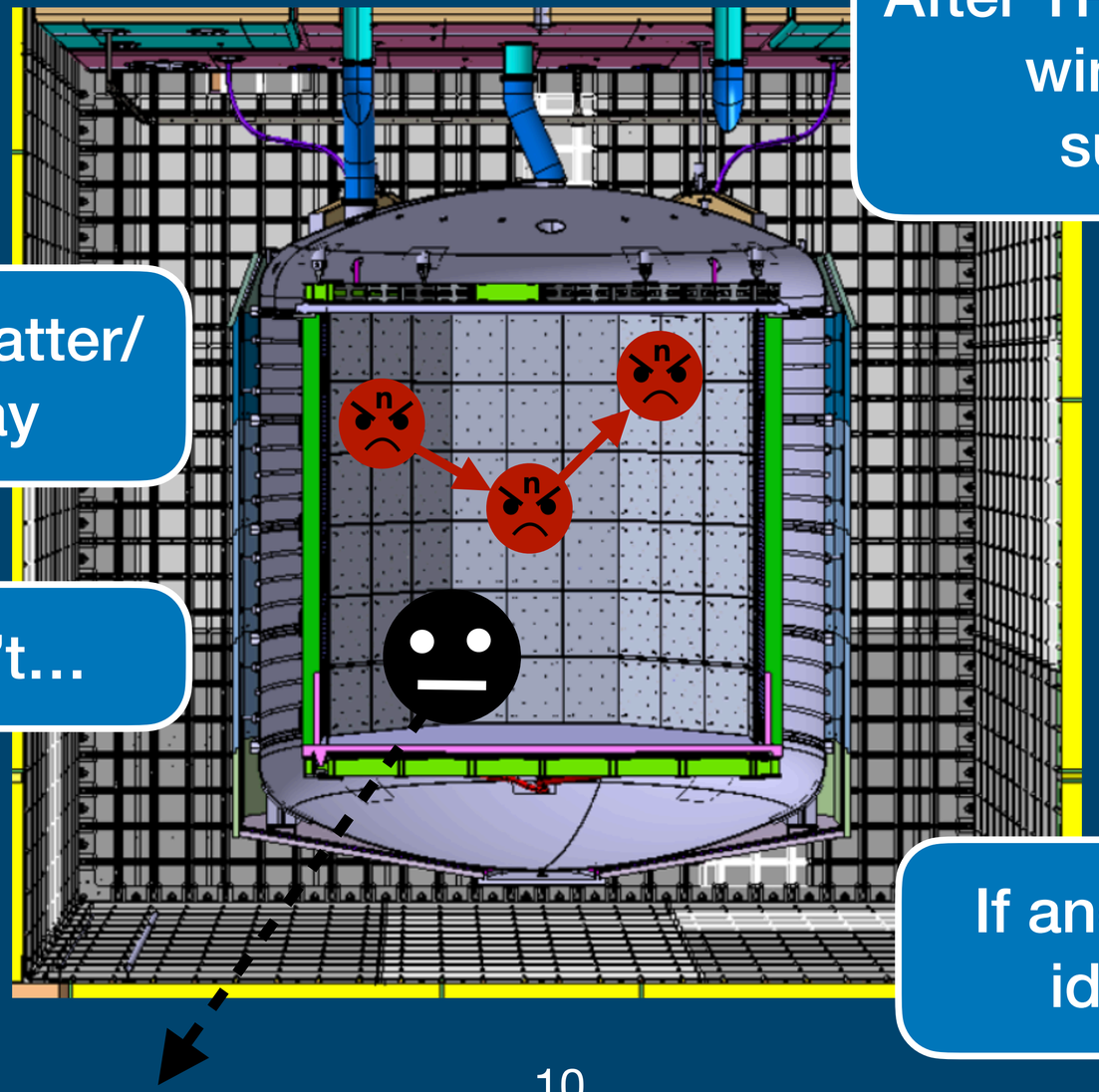
Decouple from correlated effects



Neutron Tagging

Neutrons multiple scatter/ capture and decay

Dark matter doesn’t…



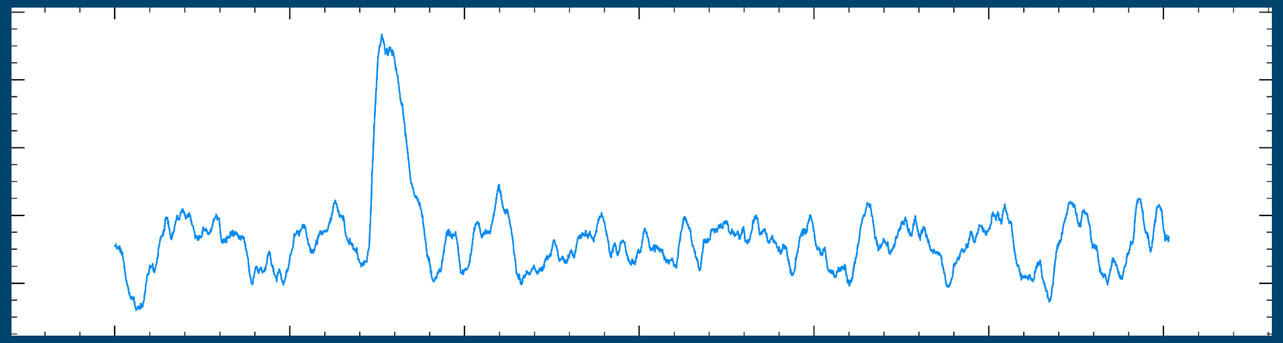
After TPC event, open tagging window and look for subsequent event

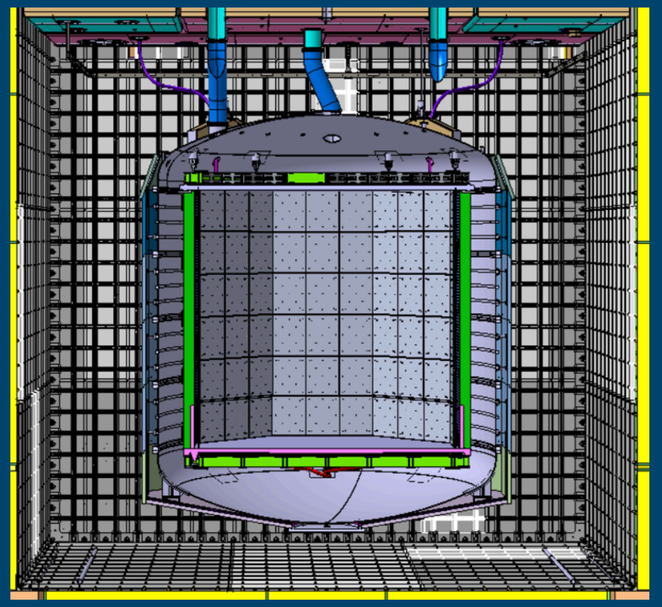


If another event is seen, identify as neutron

Neutron Inefficiency

Geant4 - Simulate neutrons to photoelectrons





IV-DSLab - Simulate SiPM and DAQ

Calculate percentage of neutrons untagged

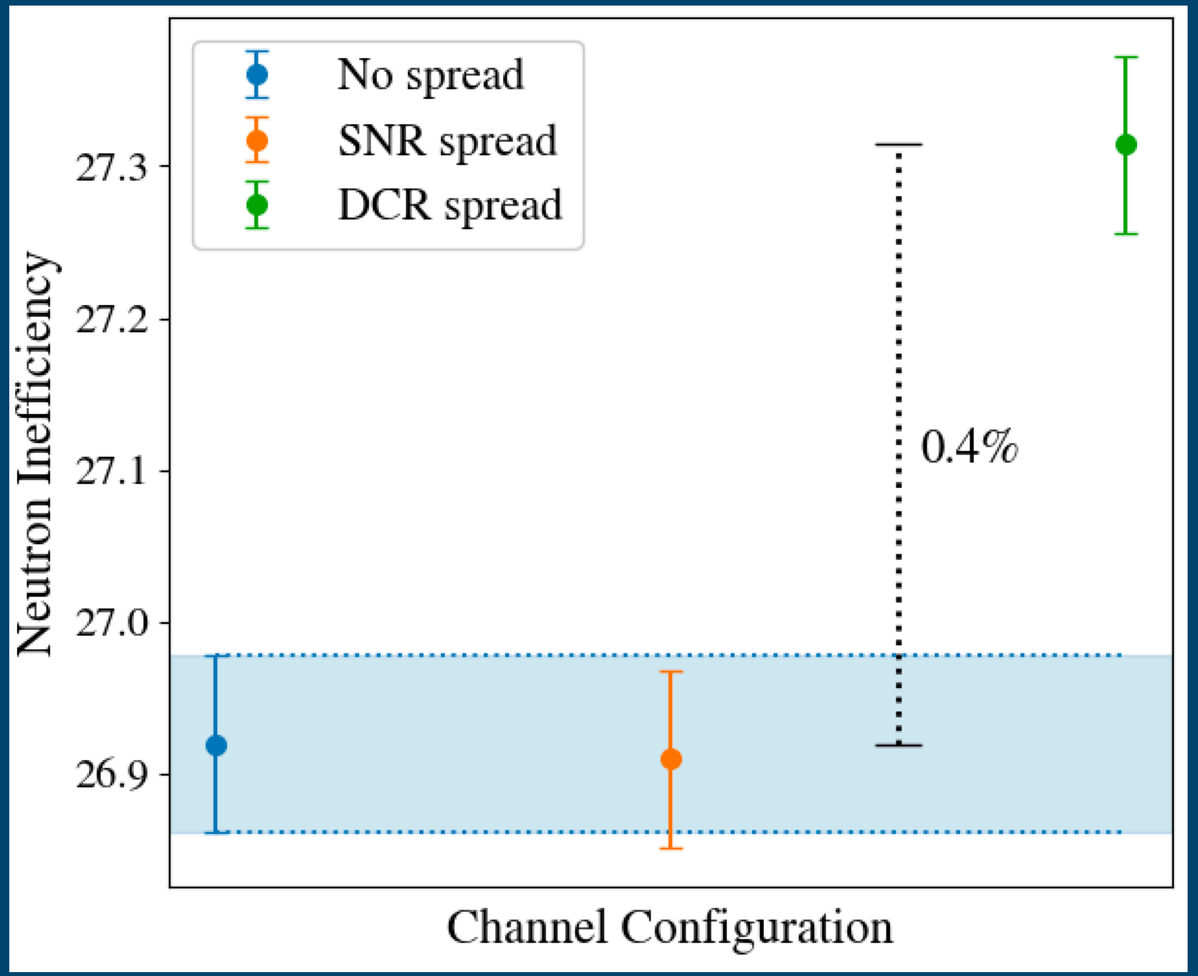


Channel Noise

Sample SNR and DCR per channel from measurement based Gaussian distributions

No change with SNR spread

0.4% increase with DCR spread not a significant degradation



Thank you!

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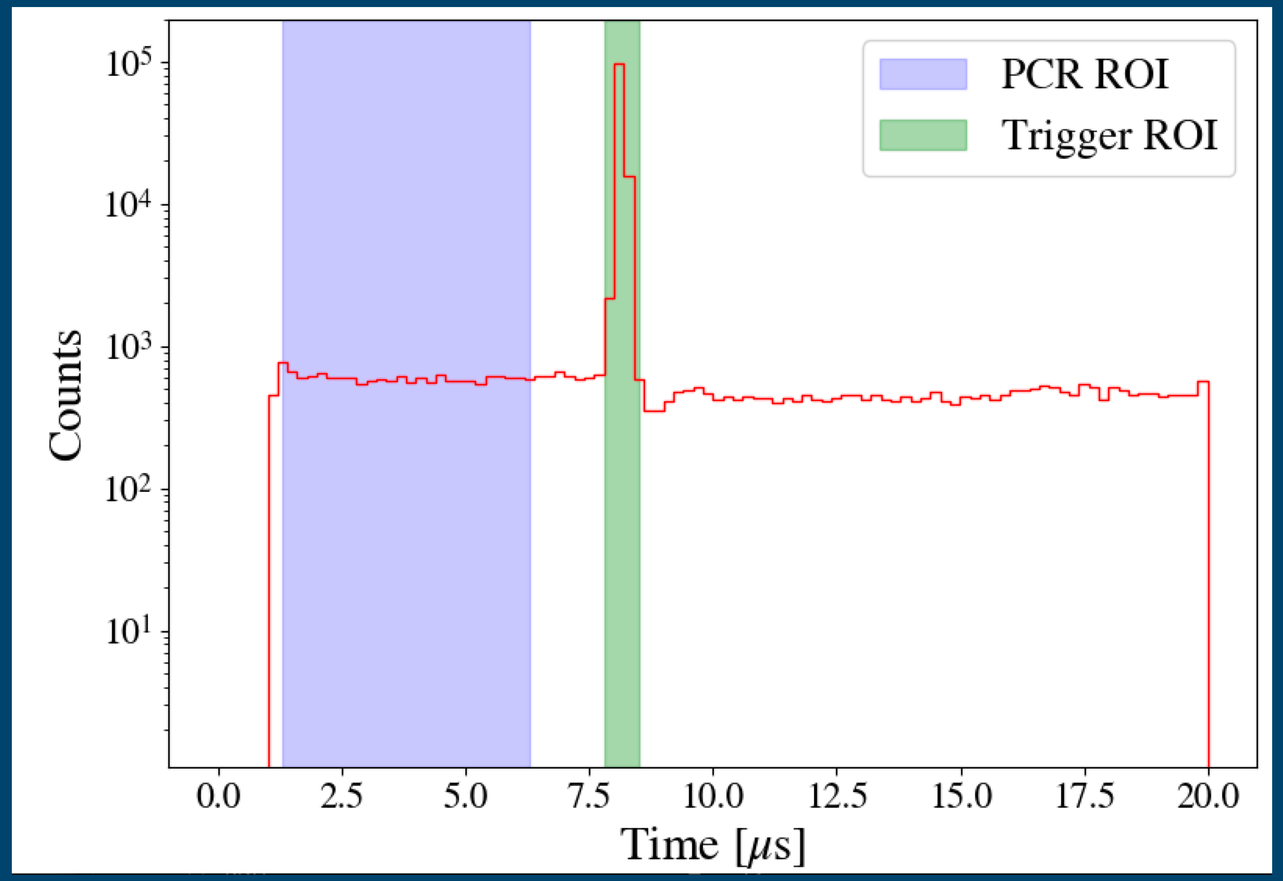
Backup

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PCR



vTile Waveform

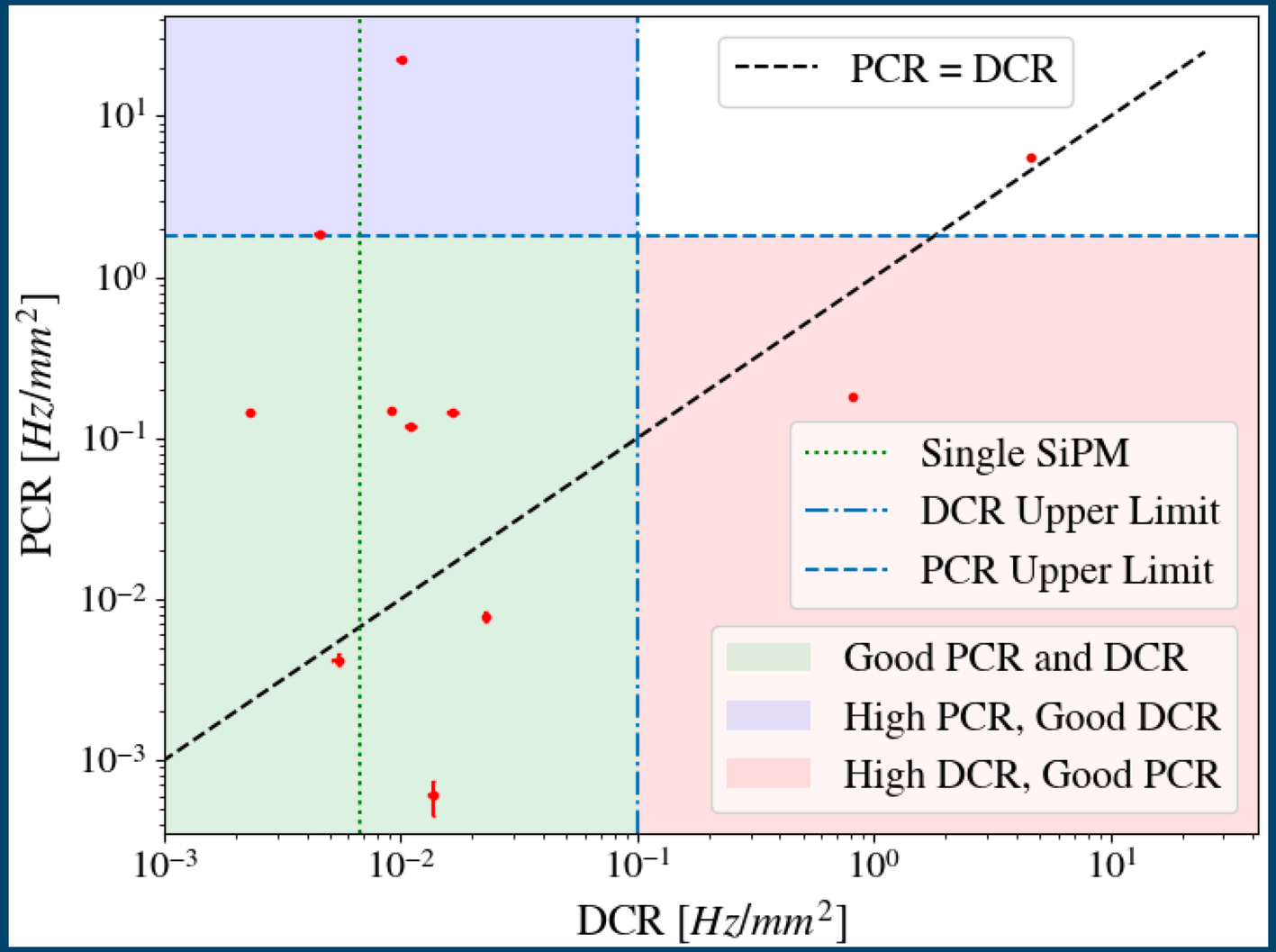
Counts DCR, as well as…

- Čerenkov in liquid nitrogen
- Emission from other SiPMs
- Reflected light in metal dewar
- Potential light leaks in apparatus
- Internal SiPM correlated noise

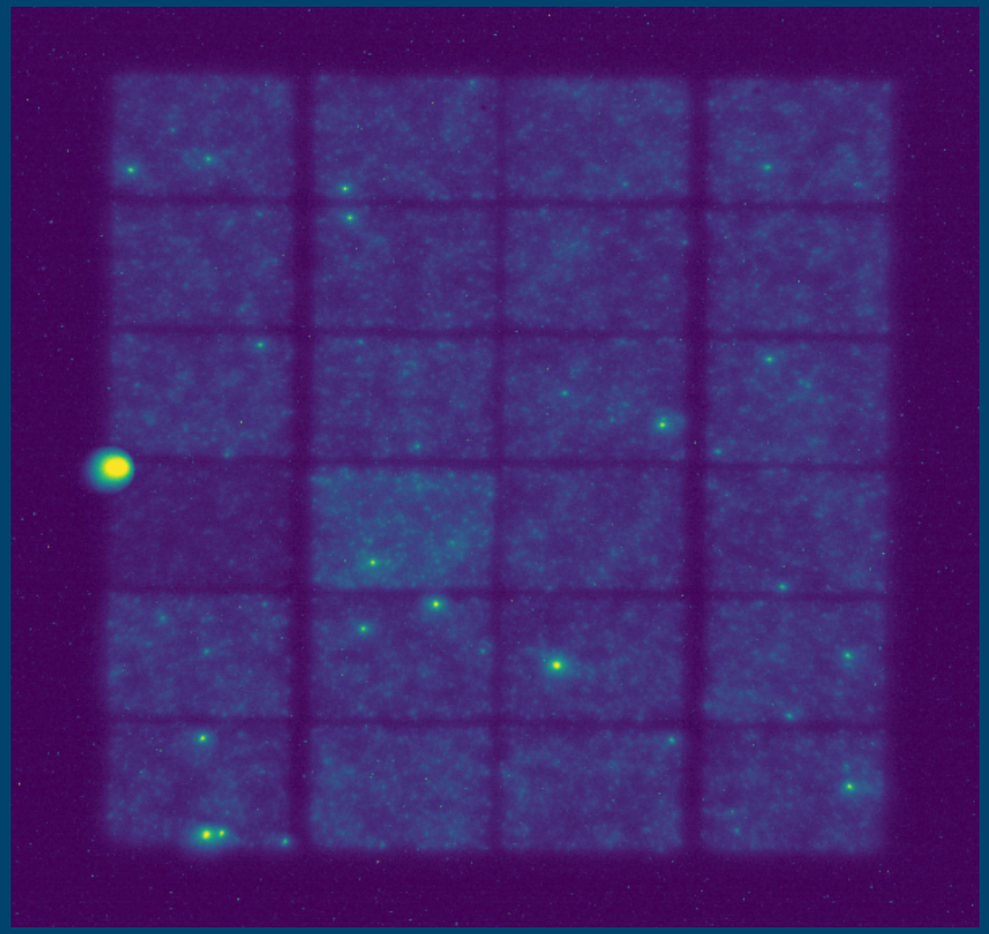
Pulse Count Rate (PCR)

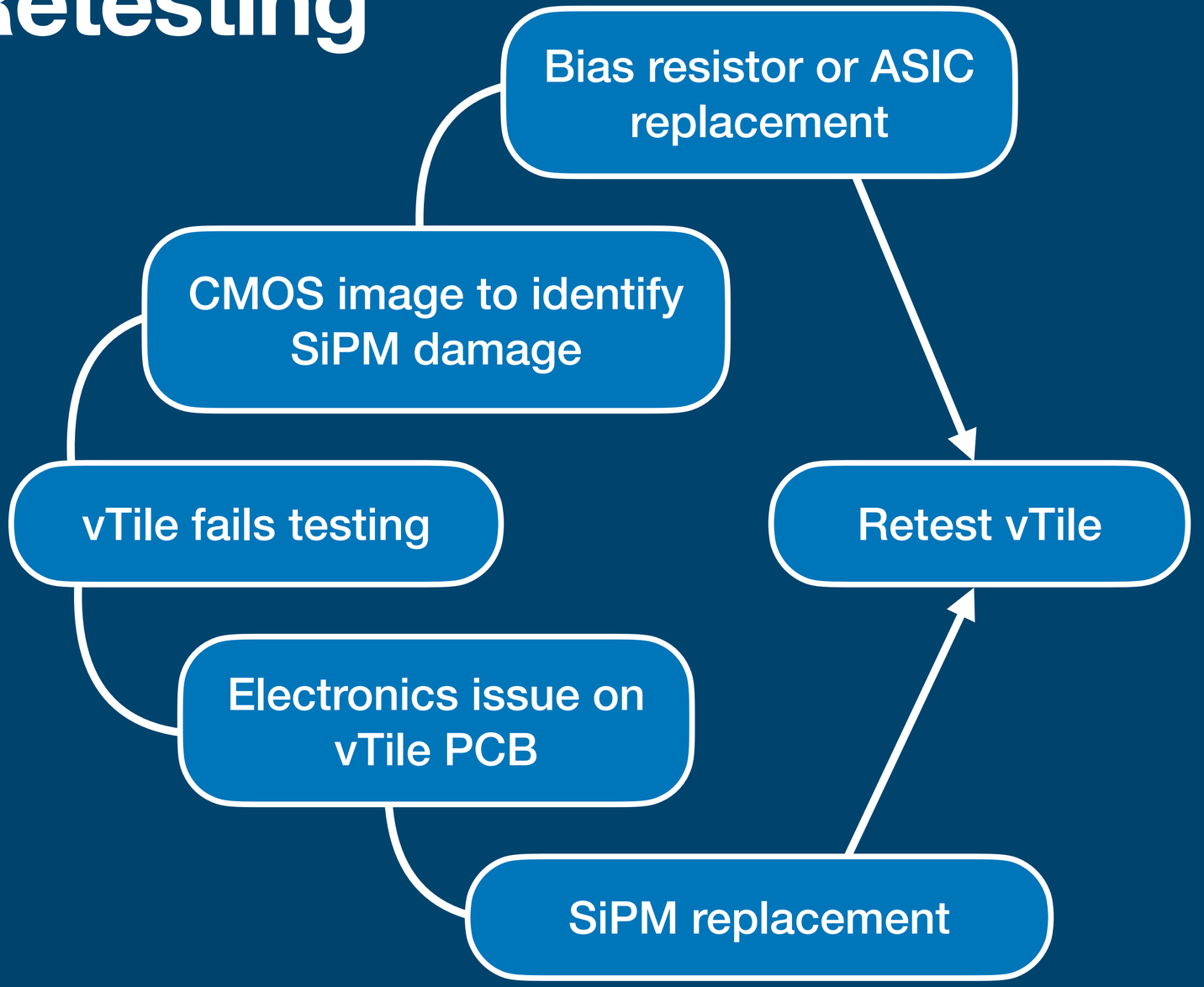
$PCR < 1.8\ Hz/mm^2$

PCR vs DCR


PCR = DCR
Single SiPM
DCR Upper Limit
PCR Upper Limit
Good PCR and DCR
High PCR, Good DCR
High DCR, Good PCR
PCR [Hz/mm^2]
DCR [Hz/mm^2]
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}

vTile Rework and Retesting





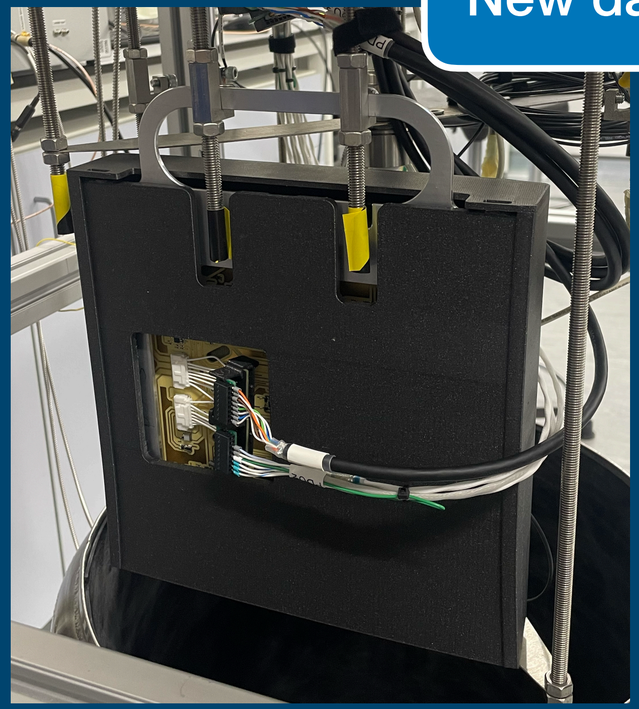
PDU DCR

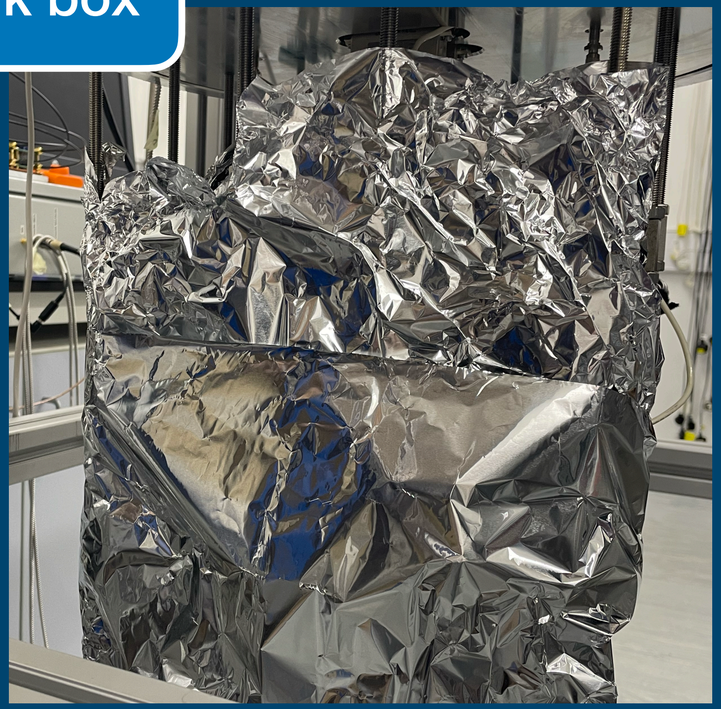
(Another…) new method for DCR

Trigger at a regular frequency with dark box on and laser off

Cannot separate DCR and correlated noise

New dark box

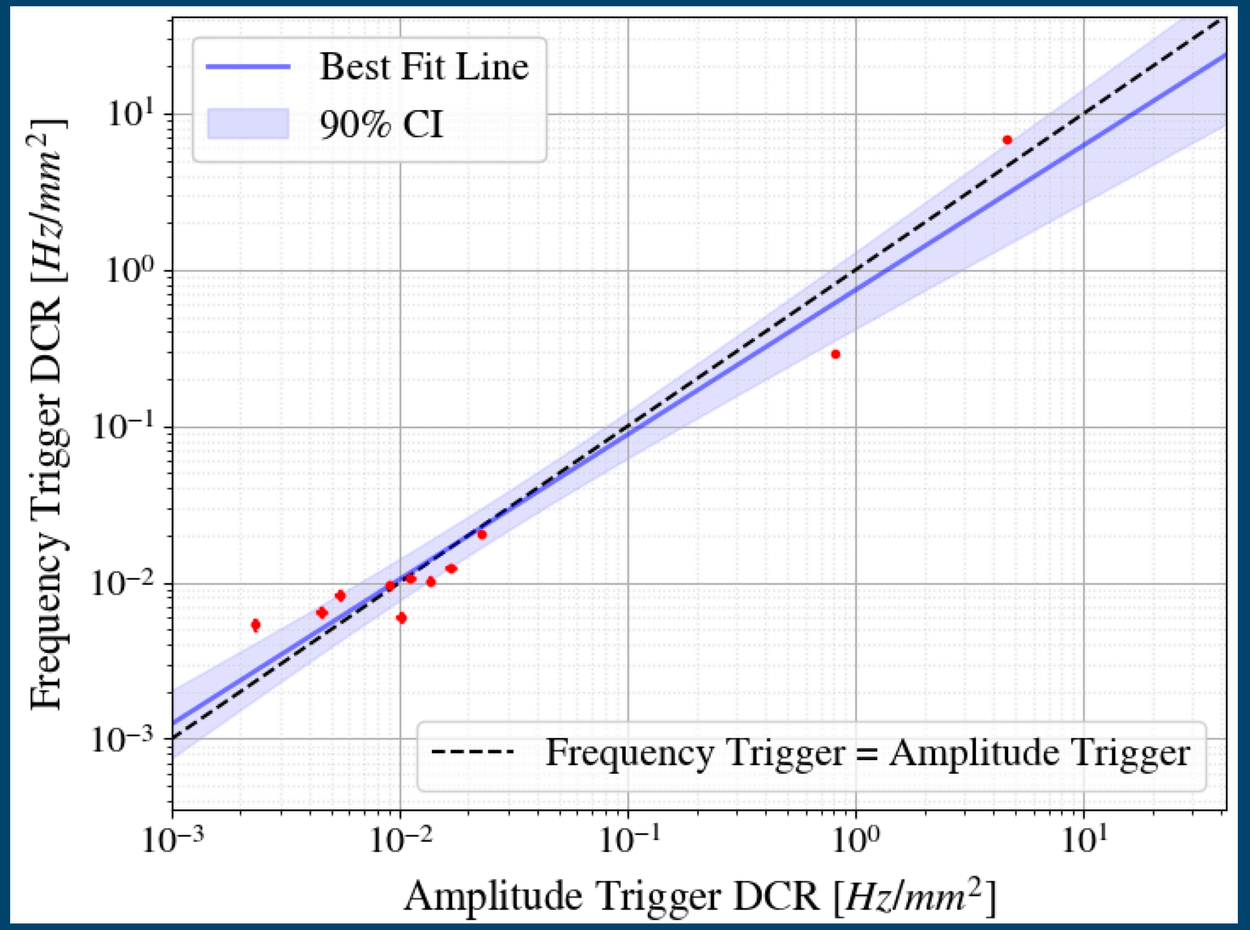




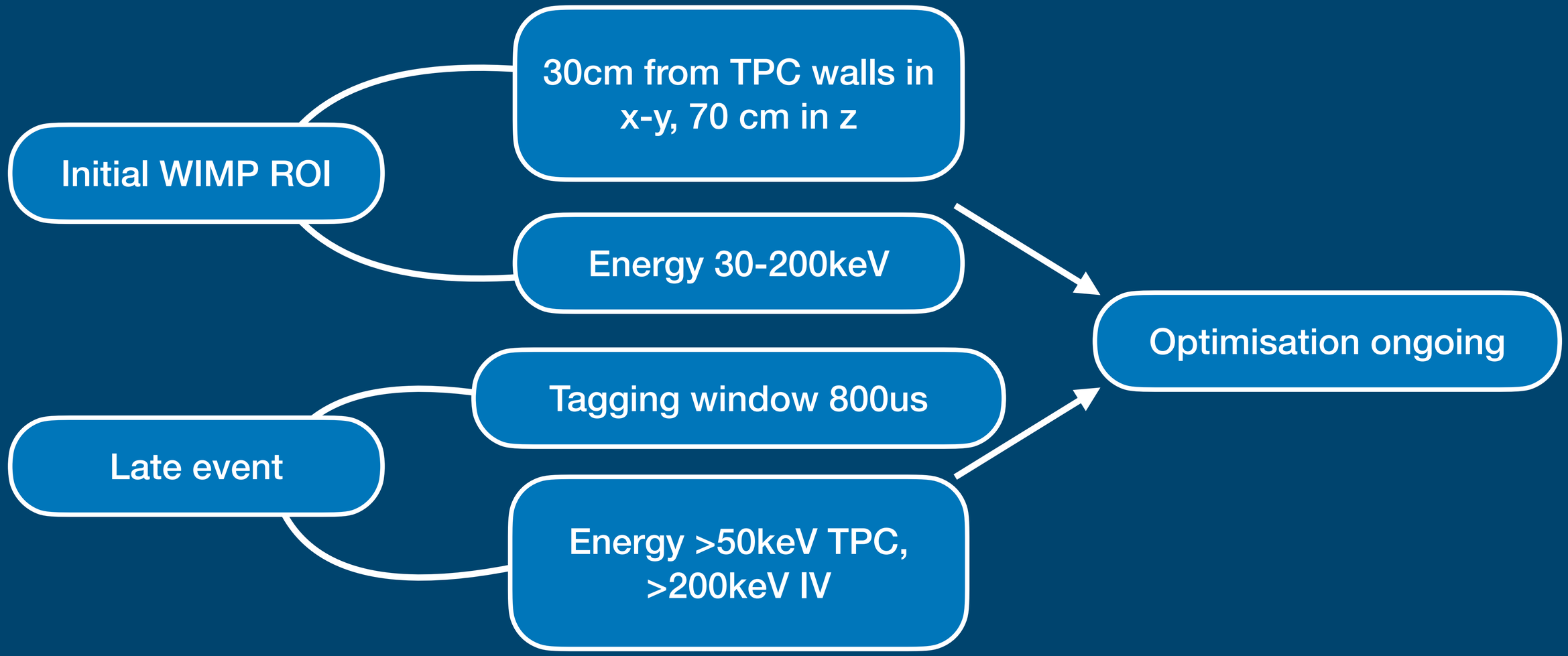
$\overline{DCR}_{PDU} = 0.0197 \pm 0.0002 Hz/mm^2$

$\overline{DCR}_{tile} = 0.0106 \pm 0.0001\ Hz/mm^2$

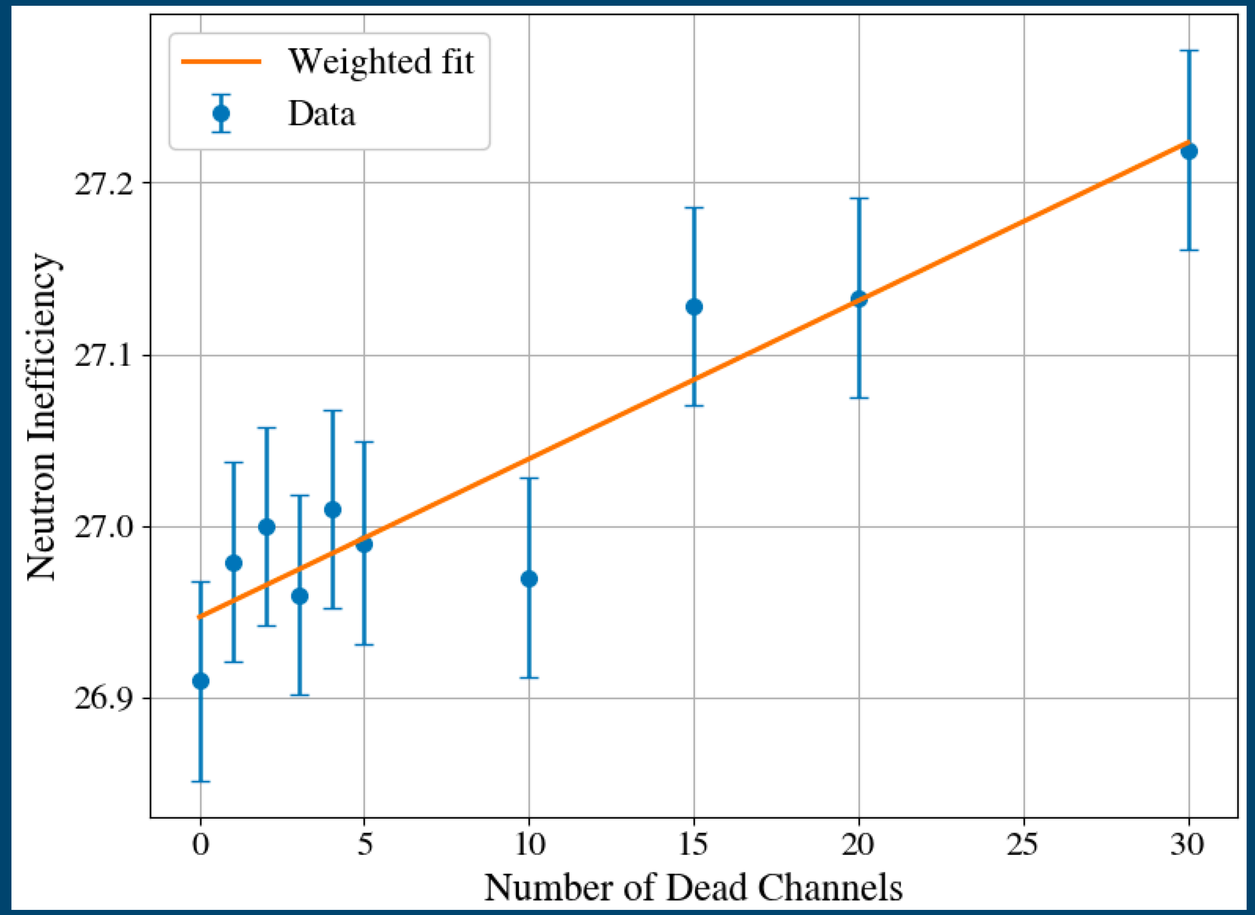
Validating vPDU Dark Box Method



Neutron Inefficiency Thresholds



Dead Channels



Randomly generate channels (out of 480) to switch off

Simulate waveforms with PE = RMS = 0

~0.009% inefficiency increase per dead channel

Very weak dependence for sparse, isolated dead channels

More work to be done…